EERL 71-3

PB 202 414

RADIOLOGICAL SURVEY AROUND POWER PLANTS USING FOSSIL FUEL

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PB-202 414

BIBLIOGRAPHIC DATA SHEET	1. Report No. EERL 71-3	2	3. Recipient's Accession No.
4. Title and Subtitle: Radiological Survey Around Power Plants Using Fossil Fuel			5. Report Date: July 1970
			6.
7. Author(s): P.H.Bedrosian			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Environmental Protection Agency, Eastern Environmental Radiation Laboratory, P.O.Box 61, Montgomery, Alabama 36101			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address: Environmental Protection Agency, Office of Research & Monitoring, Rockville, Maryland 20852			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

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17. Key Words and Document Analysis. 17a. Descriptors

Radioactivity; Steam Power Plants; Power Plant Discharges; Air Sampling; Airborne Particulates; Fossil Fuel; Lung Dose

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 18. Nuclear Science & Technology

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	UNCLASSIFIED	29
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (10-70)

USCOMM-DC 40329-P71

EERL 71-3

RADIOLOGICAL SURVEY AROUND POWER PLANTS USING FOSSIL FUEL

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July 1970

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FOREWORD

The Environmental Protection Agency has the responsibility of carrying out a national program for measuring the population exposure to ionizing and nonionizing radiation and for assessing the radiological quality of the environment.

The Eastern Environmental Radiation Laboratory (EERL) contributes to this program through research, applied technology, and training. These endeavors include the development of analytical and radiochemical methodology and the planning and presentation of courses on the radiological health aspects of ionizing and nonionizing radiation.

Until December 1970, the EERL was part of the Department of Health, Education, and Welfare and was known as the Southeastern Radiological Health Laboratory. At that time, pursuant to the President's Reorganization Plan No. 3, the Laboratory was transferred from the Bureau of Radiological Health, DHEW, to the newly created Environmental Protection Agency and given its present designation.

The technical reports of the EERL provide a rapid and comprehensive means for publishing results of intramural and contractor projects. The reports are distributed to regional, State, and local radiological health agencies, to universities and libraries, to other government and private agencies, and to interested individuals. Readers are encouraged to send their comments on the material contained in these reports to the Office of Research and Monitoring.

William A. Mills

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Acting Chief
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PREFACE

Contributions of radioactive materials to the environment arise from sources other than those associated with the nuclear industry. One such source is the steam power plant burning fossil fuel, including oil and particularly coal. These facilities release fly ash, which contains radionuclides such as uranium, radium and thorium and which represents a source of radiation exposure to man.

This report considers the environmental radioactive contribution related to selected fossil-fuel-burning steam power plants. Emphasis has been placed on a single coal-burning installation and the sampling techniques used to obtain data for estimating radiation exposure to man.

Charles R. Porter
Director
Eastern Environmental Radiation
Laboratory

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ABSTRACT

Release of radioactive materials in fly ash discharged from steam power plants burning fossil fuel, particularly coal, was investigated. Air sampling techniques were developed to provide useful data for use in estimating dose to critical organs, primarily lung, in man. Procedures are described for collecting air samples at environmental sites remote from the power plant facility.

THE AUTHORS

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* When the work described in this report was begun, this Laboratory was part of the Lepartment of Health, Education and Welfare, Bureau of Radiological Health and was designated as the Southeastern Radiological Health Laboratory, referred to herein as SERHL.

RADIOLOGICAL SURVEY AROUND POWER PLANTS USING FOSSIL FUEL

INTRODUCTION

The purpose of this report is to present the results of a field study carried out in support of the Bureau of Radiological Health's programs concerned with fossil fuel and nuclear power plants. The field study was conducted by the Southeastern Radiological Health Laboratory (SERHL) to gather data for assessing the public health significance of radioactive materials discharged from fossil fuel power plants. Field surveys focused on the discharges of fly ash from the Widows Creek Steam Station, a coal-fired plant operated by the Tennessee Valley Authority.

The study began in June 1966 at an oil-burning facility of the Florida Power and Light Company at its Turkey Point site near Miami, Florida. A previous report by Gordon[1] details this phase of the study and the results and conclusions obtained. The survey was conducted for a 26-month period and involved extensive sampling of air, vegetation, soil, sea water, fresh water, silt and tap water from areas on and around the site. Radionuclides such as ^{226}Ra, ^{228}Ra, $^{228, 230, 232}Th$ and U-natural which are likely to occur in fossil fuel were selected for investigation. The report indicated that environmental radioactivity background levels of radium, thorium and uranium were sufficiently high to preclude accurate determinations of additional quantities of these isotopes discharged into the environment by the oil-burning power plant.

Low concentration of radioactive materials in oil fly ash is the main reason environmental distribution of these materials was not observed around oil-fired plants. Detection, however, of radionuclides discharged from coal-fired plants which have greater stack discharges containing higher concentrations of ^{226}Ra appeared to be more promising. Content of ^{226}Ra in coal fly ash is about 21 times greater than that for oil fly ash as based on SERHL analyses. Assuming 9 percent ash content for coal and 97.5 percent fly ash removal efficiency, a 1000-MWe coal plant will annually release about 4.5×10^6kg of fly ash.[2] This release is about four times as great as that from an equivalent oil-fired installation.

The net effect of the higher radium concentrations in fly ash and a higher fly ash discharge rate for coal plants suggested that environmental radiation contribution would be much greater for a coal plant than for an oil plant, and more likely therefore to be measurable. On this basis, a survey of the H.B. Robinson plant, a coal-fired facility at Hartsville, South Carolina, began in December 1967. Sampling, which was not as comprehensive at this site as it was at Turkey Point, was conducted through the cooperation of plant and South Carolina State Health Department personnel. Analyses of all samples, including air, soil, coal and fly ash, were made at the SERHL. At about the same time, ancillary coal fly ash samples were collected from the Tennessee Valley Authority's (TVA) Widows Creek and Colbert Creek steam power plants. Over 130 air samples, 20 water samples, 60 coal and fly ash samples, and 140 silt samples were collected from the Turkey Point, Hartsville, and TVA plant sites during this study. More than 1400 analytical determinations were made for all these samples. Resulting data indicated essentially no increase in environmental levels of radionuclides in the vicinity of the coal plant at Hartsville. In this respect, these data were as limited as those collected from the survey of the oil plant at Turkey Point.[1] Because no measurable environmental distribution of fly ash from the Hartsville plant was found, the Widows Creek coal plant which had a lower fly ash removal efficiency, significant stack discharges, and clearly delineated plume paths, was selected for further study.

The Widows Creek plant is located near Bridgeport, Alabama. Operational characteristics of its eight units are listed in table 1. On February 24, 1969, a preliminary investigation of the Widows Creek environs was made to assess the sampling requirements and methods needed to conduct an effective survey. Results of soil and fly ash samples collected during this period indicated low but measurable levels of radium in the area of the power plant. Guided by these data, a survey of the plant environs was planned for May 13, 1969. Air was selected as the chief environmental medium to be collected for assessing environmental distribution of radioactive materials discharged from the plant and for evaluating radiation dose, namely, lung dose, to individuals in the general population.

SURVEY PROCEDURES

An air sampling technique, modified to increase collection efficiency and to provide more useful data, was used in this survey. Modification of the sampling technique involved the use of a nested

or graded filter system[3] and the orientation of the samplers in the fly ash plume at about 1.2 m above the ground. The nested filters (figure 1 and table 2[4]) consisted of five filters arranged in tandem, from course to fine. This arrangement provided data characterizing the particle sizes for use in estimating lung dose attributed to inhalation of radioactive particles. A sampler with a single filter was positioned alongside each nested unit for comparison purposes.

Sampling of the plume area was conducted by placing eight samplers at sites located longitudinally and transversely on a grid along the plume path as depicted in figure 2. Location of the air samplers in this area was based on micrometeorological factors existing at the time of the survey. The air sampling stations were operated for two days, May 13 and 14, 1969. The wind remained over the grid throughout sampling on the first day. On the second day, however, it shifted from the grid, and air data based on samples collected during this period were not considered usable except for station 8, the control. Station 8 sampler operated upwind of the plant for 3 1/2 hours before it malfunctioned on the first day and ran for 3 1/2 hours on the second day to provide a background sample of airborne dust. High volume samplers (1.8 m^3/min) equipped with 20 cm x 22 cm sampling heads utilizing glass-fiber filters were operated for a period of about seven hours for each station. During this time seven of the steam plant's eight units were at approximately 95 percent capacity emitting about 32,700 pounds of fly ash per hour; Unit 8 was shut down. Units 1 through 6 (140 MWe each) collectively emitted fly ash at 20,700 lbs/hr; Unit 7 (575 MWe) emitted 12,000 lbs/hr. These emission data were calculated from information obtained on the Widows Creek plant and from operational data on the plant (table 1).

Air samplers were placed at predetermined locations and in accessible areas within the expected plume path. Portable generators provided electricity for the high-volume blowers. Samplers and generators were checked periodically to verify proper operation. Sampling continued only while the plume was heading toward the sampling area. At the end of the sampling period, each filter was packaged in a plastic bag and shipped to the SERHL for particle size and radioactivity determinations.

RESULTS

Particle size determinations were performed by microscopic analysis of the nested filters. The data for each station (table 3) indicate that the mean diameter of practically all airborne particulates sampled in the plume path ranged from 1.2 to 9 microns with little variation noted in the particle distribution in the plume area. These results indicate that the graded filter system was not necessary for separating respirable particles (< 10 microns) from nonrespirable particles.(5)

Accurate determination of radioactivity related to the material collected on the nested filters was not possible because of significant interference by multiple filter background radioactivity levels. Analysis of filters from the single system, however, proved more successful because the radioactive particulates were concentrated on one filter. The combined radioactivity of these particles was sufficient to be distinguished from filter background.

All air sampling data from the single filter system are shown in tables 4 and 5,(6) including the filter background levels for radium-226, U-natural, thorium-232, thorium-230 and thorium-228 (table 4). These background values were subtracted from the total filter levels to obtain net radioactivity concentrations for calculating lung doses following ICRP recommendations.(7) Accordingly, these doses were determined by using the general equation:

$$D = \left[\frac{Pa\ A}{(MPC)^{x}_{a} A} + \frac{Pa\ B}{(MPC)^{x}_{a} B} + \text{---} \right] L^{x}$$

where:

D = dose to critical organ (μrem/hr)

$Pa\ A$ = concentration of radionuclide A found in air (μCi/cc)

$(MPC)^{x}_{a}A$ = maximum permissible concentration of nuclide A in air for critical organ x (μCi/cc)

L^{x} = permitted dose rate for critical organ x. For lungs this rate is 171 μrem/hr (1.5 rem/a).

Net concentrations of radionuclides in air are shown in table 5 and describe environmental contribution by the plant during the survey. These data also support the usefulness of the air sampling techniques used and particularly the concept of sampling air on a grid within the

plume path. The air data reflect additional information more recent than that previously published by Martin et al and are used to calculate lung doses (table 6) which are comparable to Martin's estimates.[8] Lung dose calculations were made on the assumption that fly ash is insoluble in body fluids. Laboratory tests measuring the solubility of fly ash in distilled water tend to corroborate this assumption.

Tables 7, 8, and 9, respectively, contain summaries of analytical results for coal, fly ash and soil samples that were collected for the Widows Creek site. These data were used in designing the field survey and are documented to indicate environmental radiation levels.

SUMMARY

Air sampling data support the feasibility of measuring airborne radioactive materials related to discharges from coal-burning power plants such as the Widows Creek facility. A successful sampling procedure for collecting measurable quantities of airborne particulates was achieved by stationing ground level air samplers at preselected sites within the expected plume path. Resulting air data described concentrations of radioactive materials at levels practical for use in determining lung dose to individuals in the population. For the Widows Creek environs, the hourly lung dose, ranging from 0.28 μrem to 1.23 μrem, was well within the radiation guide value of 171 μrem/hr for individuals in the general population.

Table 1. Operational characteristics for Widows Creek Steam Station during survey period of May 13, 1969

Unit #	Stack Height (m)	Fly Ash Control Device	Fly Ash Control Efficiency (%)	Power Rating for 100% Operating Capacity (MWe)	Operating Capacity on May 13 (%)
1	51.8	Cyclone	70	140	95
2	51.8	"	70	140	95
3	51.8	"	70	140	95
4	51.8	"	70	140	95
5	82.3	"	70	140	95
6	82.3	"	70	140	95
7	152.4	Elec. ppt.	60	575	95
8	152.4	" "	60	570	Not running

Table 2. Physical characteristics of filter media used in graded system(4)

Filter Media (downstream order)	Fiber Diameter (microns)	Approximate Thickness of Mat (cm)	Porosity
AAF-G 3/32 American Air Filter Company	16 ± 2	0.0762	0.0538
CM-245 Cambridge Filter Company	4	0.762	0.0067
#90 Dri-Pak American Air Filter Company	1.5 ± 0.01	0.635	0.0023
CM-285 Cambridge Filter Company	1	0.762	0.0025
1106 BH	Not Available	0.0356	5.28

Table 3. Particle size data for air samples collected by graded filter system from Widows Creek environs on May 13, 1969

Station	Range of CMD* (microns)	Remarks
1	1.7 - 7.8	
2	2.3 - 9.0	
3		Filters not investigated for particle sizing
4	1.7 - 6.0	
5	1.2 - 5.8	
6	2.3 - 8.3	Fifth filter in series for Station 6, 7 and 8 not investigated for particle sizing
7	2.5 - 6.8	
8	1.5 - 5.6	

* Count Mean Diameter range is for mean particle size from each of the five filters used at each station.

Table 4. Air sampling data for samples collected at Widows Creek Steam Station on May 13, 1969, using single filter high volume air samplers.

Station Number	Air Volume ($\times 10^8$cc)	Indicated Activity in fCi/filter[a]				
		^{226}Ra	U-Nat	^{232}Th	^{230}Th	^{228}Th
1	7.0	1660±70	4600±420	190±90	420±281	234±210
2	7.0	1200±60	3530±300	420±60	940±181	747±162
3	6.7	960±60	4320±400	180±40	580±112	636±156
4	5.6	1040±60	3710±320	350±50	724±158	833±170
5	5.8	1120±60	3070±260	490±70	964±190	1118±256
6	4.0	910±60	3590±300	320±50	648±130	724±138
7	4.9	1060±70	2590±240	260±5	420±139	791±190
8[b]	7.0	750±69	2700±230	240±50	736±120	752±174
Bkg concentration/ filter		750±30	636±33	116±10	540±133	703±258
Net air[c] bkg activity for station 8		0	2060	120	200	50

(a) The error expressed is in femtocuries relative to 2-sigma counting error.

(b) Station 8, the control for this survey, was placed upwind to measure background airborne dust.

(c) Net background activity is derived from activity level of control station 8 minus filter background activity.

Table 5. Concentrations of airborne radionuclides in the environs of the Widows Creek Steam Station operating on May 13, 1969

Station Number	Net Air Concentrations* (fCi x 10^{-6}/cc)					
	^{226}Ra	U-Nat	^{232}Th	^{230}Th	^{228}Th	^{228}Ra**
1	1.30	2.72	N.D.	N.D.	N.D.	0.78
2	0.64	1.19	0.26	0.29	N.D.	0.38
3	0.31	2.55	N.D.	N.D.	N.D.	0.19
4	0.52	2.54	0.24	0.04	0.16	0.31
5	0.64	1.25	0.47	0.44	0.65	0.38
6	0.40	4.43	0.33	N.D.	N.D.	0.24
7	0.63	1.04	0.12	N.D.	0.11	0.38
8	0	0	0	0	0	0

* Net air concentration reflects subtraction of air and filter backgrounds to obtain net contribution by plant discharge.

** Radium-228 concentrations in coal fly ash were assumed to be 0.6 that of radium-226 as based on data by Eisenbud *et al.* (6)

N.D. Non-detectable above filter and normal dust background.

Table 6. Estimate of lung dose rate to individuals of general population in environs of Widows Creek Steam Station as based on air samples collected May 13, 1969

Station Number	µrem/hr						Total Dose Rate
	^{226}Ra	U-Nat	^{232}Th	^{230}Th	^{228}Th	^{228}Ra	µrem/hr
1	0.11	0.23	N.D.	N.D.	N.D.	0.13	0.47
2	0.05	0.10	0.11	0.17	N.D.	0.07	0.50
3	0.03	0.22	N.D.	N.D.	N.D.	0.03	0.28
4	0.04	0.22	0.10	0.03	0.14	0.05	0.58
5	0.05	0.11	0.20	0.26	0.54	0.07	1.23
6	0.03	0.38	0.14	N.D.	N.D.	0.04	0.59
7	0.05	0.09	0.05	N.D.	0.09	0.07	0.35
8	0	0	0	0	0	0	0

* Station 8 is the background control and therefore net values with background subtracted would be zero.

N.D. Non-detectable.

Table 7. Widows Creek Steam Station coal samples collected during May 1969

Sample Identification	% Dry[b]	% Ash	Indicated Activity in pCi/kg[a]				
				Gamma Activity (Dry Sample)		Specific Alpha Activity (Ash)	
			^{226}Ra (Dry)	^{40}K	^{214}Bi	U-Nat	^{232}Th
West Kentucky	91.0	13.0	400±4	1100±1010	740±330	11550±820	580±40
East Tennessee	96.0	13.5	60±2	2800±950		6530±450	510±40
North Alabama	89.0	27.0	260±5	5600±1010	560±290	6880±530	430±40
Plant Units #1 - #6	94.0	21.0	260±7	4500±990	460±290	2010±200	2010±100
Plant #7	87.3	16.0	310±6	1900±1050	360±320	2260±190	2330±200
Plant #7	90.6	19.0	170±4	3900±980		2090±180	870±60
Plant Units #1 - #6	93.8	16.0	160±3	4700±990		1390±60	190±60

(a) The error expressed is in pCi relative to 2-sigma counting error.

(b) The percent ash is based on the dry weight.

Table 8. Widows Creek Steam Station fly ash samples collected during April - May 1969

Identification	(b) % Dry	% Ash	Indicated Activity in pCi/kg(a)							
				Gamma Activity (Dry Sample)					Specific Alpha activity (Ash	
			^{226}Ra(dry)	^{144}Ce	^{106}Ru	^{95}Zr-^{95}Nb	^{40}K	^{214}Bi	U-Nat	^{232}Th
Widows Creek Steam Plant	99.0	97.0	3330±33	800±140	1900±490		16500±1320	4800±380	10620±780	610±40
Widows Creek Steam Plant	96.0	96.9	1830±27	2600±490	720±370		17500±1050	4100±290	9240±600	400±30
Plant Units #1 - #6	86.0	94.0	1020±15		965±540		28600±1720	1820±360	1860±170	1780±120
Plant Unit #7	85.8	97.0	2240±25				21000±1470	2840±400	3840±370	1850±120
Plant Unit #7	97.2	95.0	1660±20	3100±560	790±430	200±100	19100±1150	3000±330	3770±350	1470±110
Plant Units #1 - #6	98.4	92.0	1130±17				25600±1540	1600±380	2010±200	2010±100

(a) The error expressed is in pCi relative to 2-sigma counting error.

(b) The percent ash is based on the dry weight.

Table 9. Widows Creek Steam Station soil samples collected during February - May 1969

Sample Identification	(b) % Dry	% Ash	Indicated Activity in pCi/kg[(a)]								
				Gamma Activity (Dry Sample)						Specific Alpha Activity (Ash)	
			^{226}Ra (Dry)	^{144}Ce	^{137}Cs	^{106}Ru	^{95}Zr-^{95}Nb	^{40}K	^{214}Bi	U-Nat	^{232}Th
1.6 km south-easterly from plant	100	92	670±13	1300±360	700±80		100±60	5700±680	700±20	980±30	880±60
5.4 km westerly from plant	100	93	740±15	1000±380	1400±80	1100±320	100±60	2300±620	730±260	1130±70	850±500
5.4 km westerly from plant and beneath building	100	96	850±17	1000±320	370±70			2300±580	800±180	1140±70	780±10
2.7 km north-easterly from plant	100	89.9	820±15	4030±1050	2800±110	1070±810	340±90	4900±1180	2260±590	1010±300	1090±60
5.9 km north-easterly from plant	100	97	510±11	4400±840	2520±100	1410±650	250±70	6800±950	1610±450	1190±70	100±20

(a) The error expressed is in pCi relative to 2-sigma counting error

(b) The percent ash is based on the dry weight.

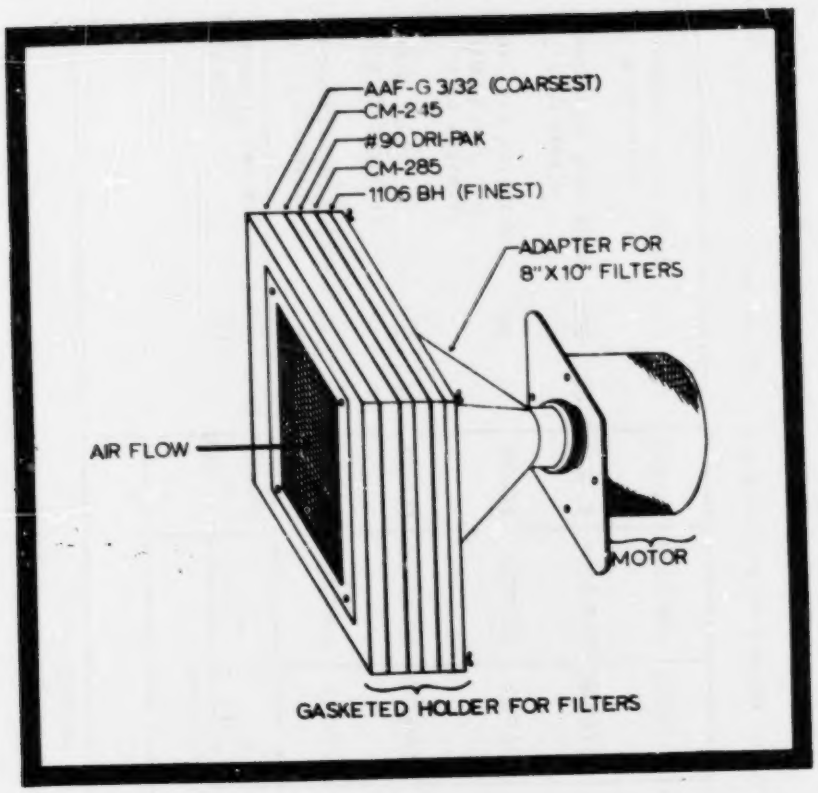

Figure 1. Nested filter system.

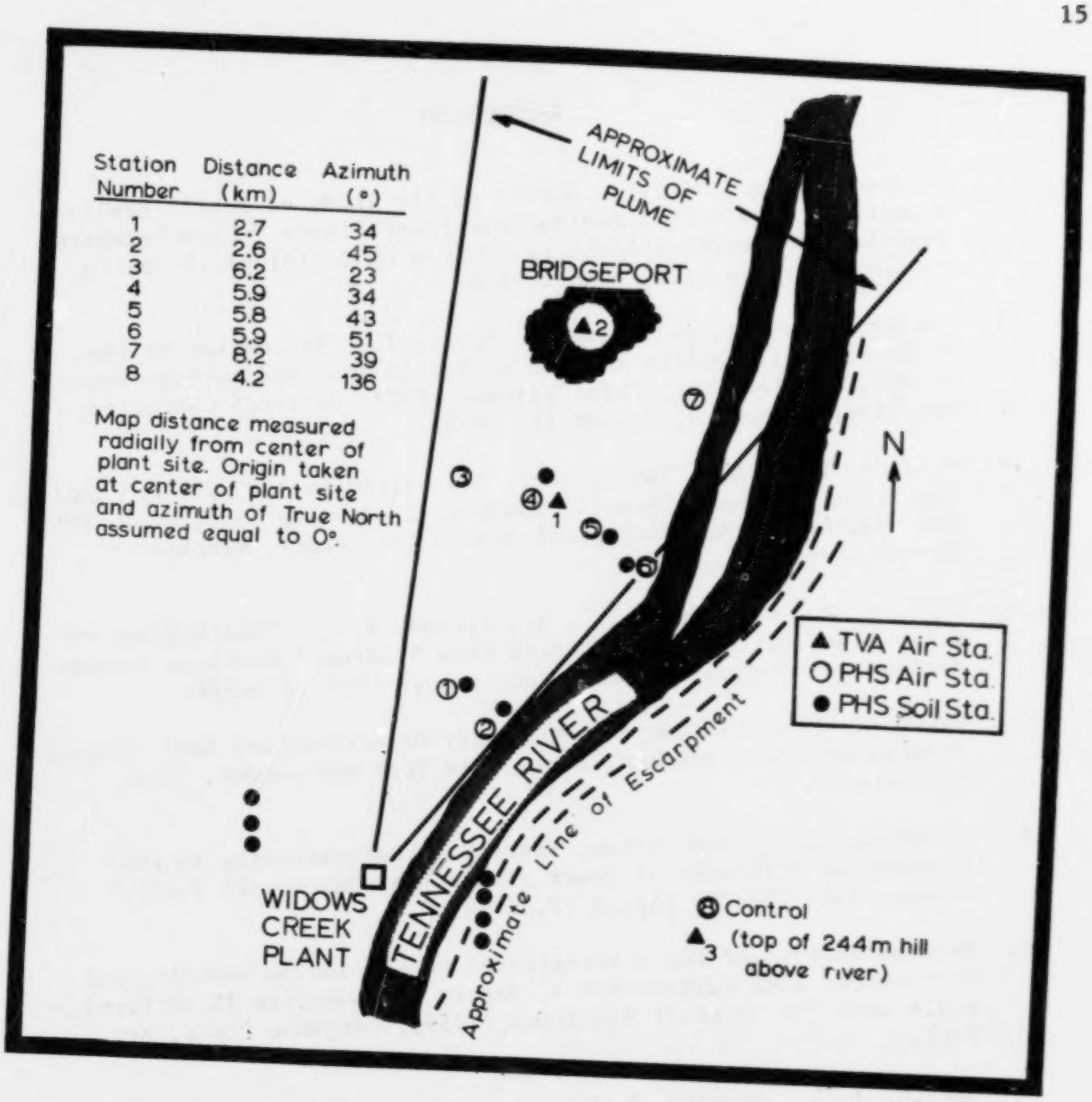

Figure 2. Sampling locations for Widows Creek Steam Station

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